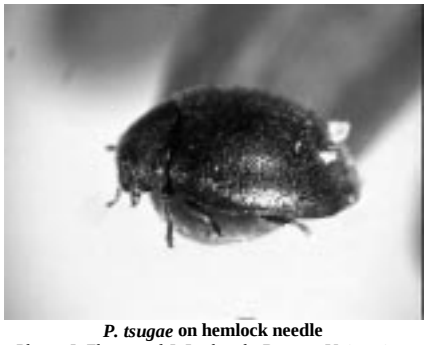
Release of *Pseudoscymnus tsugae* (Coleoptera: Coccinellidae) on the Hemlock Woolly Adelgid, *Adelges tsugae* (Homoptera: Adelgidae) in NJ

Annual Report 2002



***P. tsugae* on hemlock needle**
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Abstract

In 2002 the NJ Department of Agriculture's Phillip Alampi Beneficial Insect Laboratory released 40,260 *Pseudoscymnus tsugae* onto the hemlock woolly adelgid (HWA) into five sites in Northern NJ. The total number of beetles released in NJ since 1998 is 261,200 into 52 sites. Overwintering recoveries were made from Worthington State Forest, a 1998 release site and from Wawayanda State Park. Overwintering recoveries of *P. tsugae* have been made at 11 sites. Recovery of *P. tsugae* on stressed trees is difficult due to dieback caused by the HWA and the low HWA population levels in NJ in 2002. Approximately 290,000 beetles have been distributed to other states since 1998.

INTRODUCTION

In the spring of 1997, under a cooperative agreement with the United States Forest Service (USFS), the New Jersey Department of Agriculture's (NJDA) Phillip Alampi Beneficial Insect Laboratory (PABIL) received 100 *Pseudoscymnus tsugae* (Coleoptera: Coccinellidae) from Dr. Mark McClure and Dr. Carole Cheah of the Connecticut Agricultural Experiment Station (CAES) to serve as a back up to their colony. One of the goals of the PABIL was to try to further develop and refine the rearing procedures for *P. tsugae*. If sufficient numbers of the beetle were produced, they would be released in NJ. Beginning in 1998 and continuing through 2001, a total of 261,200 *P. tsugae* has been released into NJ forests. A little over half of the production at Phillip Alampi Beneficial Insect Laboratory, approximately 290,000 beetles has been shipped to other northeastern states infested with the HWA.

Overview

The hemlock woolly adelgid (HWA) (*Adelges tsugae* Annand) is a catastrophic introduced pest of hemlock trees in the eastern United States. The adelgid feeds at the bases of needles, desiccating them, causing needle loss and preventing the trees from producing new growth. After a forest stand has become heavily infested with the HWA, tree mortality may develop in as little as three years. Some trees have survived as long as 13 years but their vigor is greatly reduced. In an effort to save as many hemlock stands in NJ as possible, the NJDA in cooperation with the USDA-Forest Service and the Connecticut Agricultural Experiment Station has initiated a biological control program using the exotic ladybug *P. tsugae*.

P. tsugae is from Japan as is the HWA. This tiny beetle has a very narrow host range and feeds exclusively on adelgids, primarily the HWA. It has been reared and has reproduced on other adelgid species in the laboratory but not to the same extent as on HWA. The life cycle of the beetle is synchronous with that of the HWA, so much so that the beetle enters summer dormancy when the HWA does and only becomes active again when the HWA is active.

HWA is a common, but insignificant insect on ornamental and forest hemlock and spruce in Japan and China. It does not attain high densities on hemlock in Japan except for trees growing on very poor sites. There is no significant injury to the Japanese hemlocks most probably due to host resistance and the presence of native predators such as *P. tsugae* that regulate HWA populations.

The first infestations of North American hemlocks were in the 1920's in British Columbia and by the 1950's the HWA was discovered on the east coast. Both of these infestations are believed to be accidental introductions from Japan. The western North American species of hemlock (*Tsuga mertensiana*, mountain hemlock and *T. heterophylla*, western hemlock) are resistant to the HWA but the insect can be found on stressed trees. The eastern North American hemlocks (*T. canadensis*, eastern hemlock and *T. caroliniana*, Carolina hemlock) have no such resistance.

Eastern hemlocks are the successional climax trees in northern NJ forests. Hemlock is not a valuable timber tree but the wood is used for barns, sheds, pulpwood, and landscaping. There are 274 cultivars of eastern hemlock, which makes it very important to the nursery industry and in landscapes. Hemlock is ecologically important providing

cover for deer, turkey, ruffed grouse, and others. About 90 species of birds use hemlock as a nesting site, roost site or winter shelter. Northern goshawk, solitary vireo, and the black-throated warbler require habitats provided by a hemlock forest and would be stressed should the hemlock stands be reduced for any reason (Hennessey 1995). Hemlock is also an important component of some of the more popular recreational areas in NJ. Due to the dense canopy, hemlock stands are cooler in summer providing a much-needed respite from the heat for those who visit the stands.

In NJ, virtually all of the forest stands have some level of HWA infestation. In the 2001 fall survey, results of 156 monitored stands showed that 68% had an easily detectable HWA population and that 42% of those stands were heavily infested. In these heavily infested stands, over half (57%) were also heavily infested during the last survey in 1997, while 32% of the stands have increased to a heavy infestation level since the 1997 survey. The healthiest stands were in northern Passaic and Sussex Counties, but the HWA is starting to increase in this area and they will not remain healthy for long unless a biological control effort is undertaken**.** In the NJDA Permanent Study Plots, the mortality due to the HWA in the heavily infested stands ranges from 38% to 96%**.** It is not improving. The trend is for the mortality to increase in stands that are heavily infested, especially those that have been heavily infested for the second time.

HWA populations are virtually unmanageable in hemlock forests using traditional control measures. The HWA prefers new growth but can be found on old growth. Chemical insecticides are impractical to apply in the forest due to the inaccessibility of most stands, poor coverage for aerial spraying and/or excessive cost. In addition, many hemlock stands border streams and cannot be sprayed because of potential drift into the water. In heavily infested stands, the HWA multiplies quickly and can attain high densities during the first few years of an infestation. The trees are defoliated, although not completely, which causes the adelgid population to drop due to the reduced vigor and reduced new growth on the trees. The trees recover to some degree but never completely and the HWA population rapidly builds when there is abundant new growth on the trees. This leads to a cycle of decline and recovery but the trend in the cycle is ever downward resulting in tree death. Some trees survive for a number of years but only with a sparse crown at the very top of the tree. The only hope for the trees in the forest is biological control.

Biological Control

In 1992, Dr. Mark McClure of the CAES initiated a trip to Japan to attempt to find and collect some HWA predators. He discovered two: an Oribatid mite *Diapterobates humeralis* and a Coccinellid, *P. tsugae*. The mite feeds on the white, woolly, waxy secretions of the adelgid and was found to be already present in North America, but not all that effective as a control. *P. tsugae* was found to be an effective control and the USDA granted a permit for release in 1995. Although the data from these releases has not been published as yet, the results are very encouraging with the beetles having reduced the HWA population between 40% to 88% at sites in Connecticut (M. McClure, personal communication). Dr. Mike Montgomery of the USDA-FS is working with two *Scymnus* spp. from China but those species are still under evaluation and Dr. Scott Salom of Virginia Tech is working with a Derodontid beetle, *Laricobius nigrinus*.

The Case for Biological Control

P. tsugae is one of the last best hopes for the hemlocks in NJ. Evidence from Dr. McClure's work indicates that the beetles do not do as well in stands where the trees have been stressed but *P. tsugae* has been recovered from stressed stands in NJ so the jury is still out. However, to maximize their effectiveness, the beetles should be released into hemlock stands that are still vigorous. Some of the natural areas in NJ have substantial hemlock forests within them, especially those at Wawayanda and in the northeastern corner of the state. They all are infested to some degree with HWA and it is just a matter of time before the adelgid population increases to the point that the trees start to decline. By using biological control in those stands we will attempt to set up a balance between the HWA and *P. tsugae* where the adelgid is not eliminated from the stand but where the HWA population levels will be reduced to a level that the trees can tolerate. If this balance is established, the beetle and HWA populations will fluctuate in a classic predator-prey relationship but the carrying capacity for the HWA will be reduced. The timing of the releases is critical. If nothing is done, it is very likely that there will be high mortality in the remaining hemlock stands in NJ and the natural hemlock stands will be far different than they are now.

The risk of releasing *P. tsugae* is extremely small. It does not feed on anything but adelgids and is very host specific to the HWA. No native coccinellid, or other predator for that matter, occupies the same niche that *P. tsugae* does. It would not be displacing any of our native coccinellids and it would most likely have a negligible impact on other

adelgid species.

MATERIALS AND METHODS

In 2002, a procedural change was made from 2001 and previous years in all of the plots due to the difficulty in collecting population data for the HWA and *P. tsugae* (Scudder et. al. 2001). Counts of HWA were increasingly difficult to perform due to the extensive dieback on the trees and the low populations due to poor tree health in 2002. The data were extremely variable with many zeros making analysis difficult. Also, due to the low HWA populations there was a concurrent problem in that there was little for the *P. tsugae* to feed on making them difficult to find. There were time constraints as well as many more sites to monitor. With all this, it was decided to use the US Forest Service Monitoring protocols developed by Brad Onken to sample for *P. tsugae* and evaluate tree health at the release sites with the addition of the crown ratings of crown ratio and transparencies as in Millers, et. al. (1992) for twenty randomly selected trees. This was used to evaluate overall stand health and to attempt to show the effect of the *P. tsugae* over time. This is the same method used in the NJ statewide hemlock survey that was conducted in 2000 (Mayer et. al. 2002). The crown transparencies and crown ratios will allow us to compare the tree health in the stands from year to year.

The USFS monitoring protocols as developed by B. Onken were as follows: Hemlock density was marked as either less than or greater than 50%. The overall health of the hemlock was classified as Good where the foliage had normal color density and the general overall appearance is good; Fair where the foliage was somewhat off color and/or trees have thinning crowns, and the overall appearance was fair; and finally Poor where most of the trees looked stressed, the foliage color was chlorotic and/or thinning crowns and the overall appearance was poor. All other stressors were listed like drought, the presence of other pests etc. HWA densities were classified as Low where most trees were uninfested and/or most infested trees had < 10% infested branches. Moderate was where the number of infested trees was 50% or more and most infested trees had 10-50% infested branches. Heavy was defined as most trees were infested and > 50% of the branches were infested.

Monitoring for the presence of *P. tsugae* was conducted monthly if possible. Surveys were conducted at all the data sites as well as all other release sites within the state. Each site was surveyed for 2.0 people hours or until a *P. tsugae* was found. A one meter square beating sheet was placed beneath several branches and the branches were struck ten times with a plastic whiffle ball bat. Any life stages of *P. tsugae* recovered on the sheet were recorded (Figure 1).

Figure 1. *Pseudoscymnus tsugae* Sampling and Recovery

Photo by L. Bronhard

The *P. tsugae* were transported to the new release sites in Sweetheart®, 165 oz., stock number 10T1 paper buckets covered with Sweetheart® 10V19S paper lids. The buckets were very much like the fast food buckets that fried chicken comes in. There were 2,500-5,000 beetles per bucket and the buckets were filled with excelsior for increased surface area. At the release site the lid was removed and the buckets and lids were placed into the branches of the tree. After five minutes, any stragglers in the buckets were gently brushed out onto the infested branches using a soft, 1-inch paintbrush. The release trees were heavily infested with HWA and were in relatively good health.

In 2001, the Phillip Alampi Beneficial Insect Laboratory contracted with Geils Tree Service to use their 1996 International 4900 with a 60 ft. lift-all boom to survey the canopy of some release sites in order to recover *P. tsugae* that may be at the tops of the trees as theorized by M. McClure (Figure 2). The sites selected were accessible to the truck and one site was selected because it was a 2001 release. There was a discussion of this in the 2001 report but that discussion was abbreviated due to time constraints so it is expanded upon here. Two types of work were done; one was a survey of previous season's release sites but the other counted the number of adult *P. tsugae* per meter a

month and a half after the beetles were released. The tree was moderately to heavily infested by the HWA.

Figure 2. Bucket Truck Work

A string marked in one-meter increments with a weight attached was used to determine the height. The string was dropped off of the side of the bucket until the weight hit the ground. The branches were sampled by striking them with a wiffle ball bat knocking the beetles into a one meter beating sheet. The number of beetles recovered was recorded for each meter. If no branches were at a certain height then no sampling was done.

RESULTS AND DISCUSSION

The PABIL continues to provide sufficient numbers of *P. tsugae* for release both in NJ and in other states. A total of 40,260 *P. tsugae* were released into 9 sites in 2002. Table 1 summarizes the production levels and releases of *P. tsugae* from 1997 through 2002.

Table 1. *Pseudoscymnus tsugae* Production and Releases 1997 - 2002

Year	No. *P. tsugae* Released in New Jersey	No. of Sites
1997*	0	0
1998	75,500	15
1999	65,000	13
2000	50,000	13
2001	30,500	7
2002	40,260	9
Total	**261,200**	**57**

*****From a starter colony of 100 adult beetles received in May 1997

The recovery of two adults this year has demonstrated that *P. tsugae* continues to successfully over winter in New Jersey (Table 2). This is the fourth consecutive year that recoveries have been made, although the number of recoveries has been decreasing each year. There are several factors that account for this phenomenon. One is that the HWA populations are low throughout NJ. Two, the fact that living, reachable lower branches are becoming fewer and fewer on the release trees due to dieback. Three, the beetles have dispersed to the higher branches, which are unreachable by the survey personnel (Scudder, et. al. 2001).

Larvae were recovered again in 2002, but from a 2002 release site. In 2001 an overwintering larval recovery was made at the Swartswood SP boat launch site and a same season recovery was made at the Walpack WMA site on Mountain Rd. South. This is significant because it confirms that the beetles are reproducing in the field. The larvae are more challenging to find because they hang on tightly to the branches. Even if you manage to dislodge one, they are extremely difficult to find because they cling to the needles and other debris on the beating sheet, so developing a searching image for them takes some time. Also, the lack of live lower branches as explained above affects recovery of larvae.

Table 2. *Pseudoscymnus tsugae* Releases and Recoveries 1998-2002

Release Year	County	Location	Site Totals	*P. tsugae* Recovery A = adult recovery, L = larva recovery			
				1999	2000	2001	2002
1998	Sussex	Wawayanda State Park	10,000	A			
1998	Sussex	Kittatinny Valley State Park	10,000	A			
1998	Sussex	Stokes State Forest	10,000	A			
1998	Warren	Jenny Jump State Forest	10,000	A			
1998	Sussex	Johnson Lake Plot	3,000		A		
1998	Sussex	Sparta Glen	6,000				
1998	Morris	Schooley's Mountain Plot	3,000				
1998	Morris	Lake Valhalla Plot	5,000				
1998	Warren	Shades of Death Plot	2,500				
1998	Warren	Worthington State Forest	5,000	A	A		A
1998	Mercer	Washington Crossing State Park	1,500				
1998	Mercer	Princeton Battlefield State Park	1,500				
1998	Monmouth	Walnridge Farm Plot	3,000				
1998	Monmouth	Freer Nature Preserve	4,500	A			
1998	Monmouth	Deep Cut Park	500				
1998	**Total**		**75,500**				
1999	Hunterdon	Ken Lockwood Gorge W.M.A.	5000				
1999	Hunterdon	Pine Hill Section, S. Branch Res.	3500				
1999	Morris	Hacklebarney State Park	5000				
1999	Morris	Rockaway River W.M.A. Jefferson Twp.	5000				
1999	Passaic	Clinton Reservoir, South of PSP	4500				
1999	Sussex	Allamuchy State Park	10000				
1999	Sussex	Glenwood Mt. AT Site	5000				
1999	Sussex	High Point P.S.P.	5000				
1999	Sussex	High Point SP--AT shelter	5000				
1999	Sussex	Sparta Mt. W.M.A. Ogdensburg	2500				
1999	Sussex	Tillman's Ravine P.S.P	5000		A		
1999	Sussex	Wawayanda Hemlock Ravine	5000				
1999	Warren	Dunnfield Creek, Worthington State Forest	5000				
1999	**Total**		**65,000**				
2000	Hunterdon	Stanton Station Park Site	2500		L		
2000	Hunterdon	Westcott Preserve	2500				
2000	Hunterdon	Wickecheoke Creek Reserve	5000		L		
2000	Passaic	Newark Watershed - Cedar Pond	2500				
2000	Pike, PA	DWGNRA - Adams Creek	7500				
2000	Sussex	Flatbrook WMA	5000				
2000	Sussex	Swartswood State Park	5000			2A, 1L	
2000	Sussex	Tillman's Ravine	2500				
2000	Sussex	Wawayanda Hemlock Ravine Natural Area	2500				
2000	Sussex	Wawayanda Swamp Natural Area	2500				
2000	Sussex	White Lake WMA	2500				
2000	Sussex	Walpack WMA - Mountain Rd.	5000			L	
2000	Sussex	Stokes State Forest - Stoney Lake	5000				
2000	Sussex	DWGNRA – Van Campen's Brook	7500				
2000	**Total**		**50000**				

Release Year	County	Location	Site Totals	*P. tsugae* Recovery A = adult recovery, L = larva recovery			
				1999	2000	2001	2002
2001	Passaic	Wawayanda SP – Clinton Rd.	5000			A	A
2001	Sussex	Walpack WMA – Mountain Rd. South	5000			A, L	
2001	Sussex	Stokes SF – Rd. to Shotwell Campground	5000			A	
2001	Sussex	DWGNRA – Van Campen's Brook	5000				
2001	Sussex	Stokes SF – Lake Ocquittunk Campground	5000			A	
2001	Sussex	Stokes SF – Woods Rd. & Shay Rd.	2500			A	
2001	Sussex	Swartswood SP – Boat Trailer Launch	3000			A	
2001	**Total**		**30,500**				
2002	Sussex	Galloping Hill Road, High Point SP	7,500				19A
2002	Hunterdon	Natural Lands Trust Preserve, Milford	5,500				10A
2002	Passaic	Clinton Reservoir, Newark Watershed	3,000				
2002	Passaic	Wanaque WMA,	2,500				8A, 3L
2002	Sussex	Flatbrook WMA, North Side	1,760				

The most interesting recovery was at the Worthington State forest site where the initial release was made in 1998. Recoveries of *P. tsugae* were made in 1999, 2000 but no recovery in 2001. In 2002, the beetles were recovered again after an absence of a year. What is remarkable is that this site has stressed trees with an average crown transparency of 62.5% with a low HWA population. The beetles have established in a marginal site which indicates that they should establish anywhere they have been released.

In previous seasons counts of HWA were made in an effort to document the effect of the *P. tsugae* on the HWA population. This has proved difficult because of the fluctuation of the HWA population levels and the dieback that the heavily infested trees have experienced. The variability of the HWA population is more due the effect of the HWA on the trees rather than any effect caused by the beetle. In years with high levels of new growth, the HWA infestation increases and subsequently decreases in succeeding years when the adelgid attack has prevented any formation of new growth. The adelgid population crashes and then the trees recover, only to be infested once again several years later. The result is a defoliation of the trees over time eventually leading to mortality.

We did not expect much, if any, impact on the HWA population in 1998 because it was the first year of release and the number of beetles that have been recovered has been minimal. All introduced populations go through a lag phase in their establishment where there are few of the new species around and it takes awhile for them to enter the log phase of their population curve. *P. tsugae* is still in the lag phase and it may be some years before they can be shown to have an impact, if ever.

Very little then, can be said as yet about the impacts of the *P. tsugae* because they simply have not had time to reproduce to population levels that could control the HWA. The population levels of the HWA also affect their reproduction. If there is plenty of new growth there will be plenty of adelgid and vice versa. Logically, the beetles will be difficult to recover in an area where the adelgid population has crashed. Also, when there is dieback on a tree due to the HWA, the lower branches go first leaving less material to sample in succeeding seasons since the sampling is done from branches accessible from the ground.

Therefore, in areas that are newly infested with the HWA, the HWA population may increase rather than decrease when *P. tsugae* is released. An insufficient number of beetles have been released to have any direct dramatic immediate impact on the forest. It is too soon to determine the impact the releases may have on the HWA. The larger concern is whether sufficient releases can be made in time to produce enough *P. tsugae* to reduce the HWA population before the trees are devastated beyond recovery.

Table 3 shows the stand conditions for the NJ Department of Agriculture release sites.

Table 3. Stand Conditions for the Release Sites in 2002

			Stand Condition 2002				
Release Year	County	Location	Tree Density > or < 50%	Tree Health	HWA density	% Crown Ratio	% Crown Transparency
1998	Sussex	Wawayanda State Park	<	F	L	83.3	71
1998	Sussex	Kittatinny Valley State Park	<	P	L	48.3	80.8
1998	Sussex	Stokes State Forest	>	F	L	78	66.75
1998	Warren	Jenny Jump State Forest	<	P	H	54.5	80.8
1998	Sussex	Johnson Lake Plot	<	P	H	28	98
1998	Morris	Schooley's Mountain Plot	<	P	L	14.5	90.5
1998	Morris	Lake Valhalla Plot	<	P	H	43.8	83.3
1998	Warren	Shades of Death Plot	<	P	H	0.9	98.5
1998	Warren	Worthington State Forest	<	P	L	65.8	62.5
1998	Mercer	Washington Crossing State Park	<	F	M	68	53
1998	Monmouth	Walnridge Farm Plot	<	P	H		
1998	Monmouth	Freer Nature Preserve	<	F	H	63.5	69.8
1999	Hunterdon	Ken Lockwood Gorge W.M.A.	>	P	L	70	70
1999	Hunterdon	Pine Hill Section, S. Branch Res.	<	F	L	79.3	65.25
1999	Morris	Hacklebarney State Park	>	P	H	49	74
1999	Morris	Rockaway River W.M.A. Jefferson Twp.	<	P	L	64.3	78.8
1999	Passaic	Clinton Reservoir, South of PSP	>	P	L	58.5	79
1999	Sussex	Allamuchy State Park	<	F	L	81.8	60.8
1999	Sussex	Glenwood Mt. AT Site	<	P	H	45.8	80.8
1999	Sussex	High Point P.S.P.	>	F	H	52	72.75
1999	Sussex	High Point SP--AT shelter	>	P	H	51.5	73.8
1999	Sussex	Sparta Mt. W.M.A. Ogdensburg	>	F	M	71.3	69.75
1999	Sussex	Tillman's Ravine P.S.P	>	F	L	66	66.3
1999	Sussex	Wawayanda Hemlock Ravine	>	F	M	48.8	64.3
1999	Warren	Dunnfield Creek, Worthington State Forest	<	F	L	81.3	60
2000	Hunterdon	Stanton Station Park Site	>	F	M	71.3	65.25
2000	Hunterdon	Westcott Preserve	>	F	H	88.8	59.75
2000	Hunterdon	Wickecheoke Creek Reserve	<	F	L	70	72.75
2000	Passaic	Newark Watershed - Cedar Pond	>	F	M	81.8	60.5
2000	Sussex	Flatbrook WMA north of rt 560	>	F	M	71.3	65.25
2000	Sussex	Flatbrook WMA	<	F	L	55.5	59.5
2000	Sussex	Swartswood State Park picnic area	>	F	M	71.3	63.75
2000	Sussex	Swartswood State Park canoe launch	<	F	L	54.3	63.5
2000	Sussex	Wawayanda Swamp Natural Area	<	F	M	81	62.25
2000	Sussex	White Lake WMA	<	F	L	81.5	55
2000	Sussex	Walpack WMA - Mountain Rd.	>	F	L	76	58
2000	Sussex	Stokes State Forest - Stoney Lake	>	F	L	82	66.5
2001	Passaic	Wawayanda SP – Clinton Rd.	<	G	L	99.3	48
2001	Sussex	Walpack WMA – Mountain Rd. South	<	F	L	85	51.75
2001	Sussex	Stokes SF – Rd. to Shotwell Campground	>	G	L	92	57

			Stand Condition 2002				
Release Year	County	Location	Tree Density > or < 50%	Tree Health	HWA density	% Crown Ratio	% Crown Transparency
2001	Sussex	Stokes SF – Lake Ocquittunk Campground	>	G	M	87.3	56
2001	Sussex	Swartswood SP – Boat Trailer Launch	>	G	M	82	59.25
2002	Sussex	Galloping Hill Road, High Point SP	>	G	L	87.3	48.75
2002	Hunterdon	Natural Lands Trust Preserve, Milford	>	P	L	61.8	61
2002	Passaic	Clinton Reservoir, Newark Watershed PSP	>	G	L	54.6	36.02
2002	Passaic	Wanaque WMA,	>	G	L	69.3	59.5
2002	Sussex	Flatbrook WMA, North Side	>	G	L	70.8	49

Crown ratings were used to evaluate the health of the trees in the release plots (Table 4). Overall, the general health of the trees is declining. Data was not collected at some of the sites either because the sites were on US National Park Service property or in the case of Deep Cut Park and the Princeton Battlefield; the sites were ornamental sites with only a few trees. The release site at Woods Road and Shay Road in Stokes State Forest and the site in Sparta Glen were inaccessible. Of the 44 sites where the NJDA was able to monitor the trees, 29 sites had average crown transparencies over 60%, 11 sites had transparencies between 50-60% and 4 sites had transparencies less than 50%. Thirty-five of the sites had Low or Moderate HWA populations. Hemlock health was good in only 8 of the sites. In Mayer, et. al. (2002) hemlock mortality increased substantially in those hemlock stands with crown transparencies over 60%. Twenty-nine of the sites then, appear to be in trouble and may be past the point of no return. Releasing beetles in those sites would not be productive in the future. The releases should be concentrated in areas where the hemlocks are still relatively healthy and where the HWA populations are moderate to heavy. Geographically, all future releases should be in the northwestern corner of the state.

Much of the defoliation in 2002 was due to the extended drought conditions experienced in the northeast but some of it can be attributed to the HWA. The drought has not helped, especially in stands that have had HWA infestations since the beginning of the 1990's. Again, anytime the transparency is over 50-60%, the trees usually even though it may take five years or more. From personal observation, trees that have been treated with insecticides can come all the way back if their transparencies are greater than 50% but that involves a lot of expense and work and is impractical in the forest. The effects of the drought will not be known for some years because Onken (1994) discovered that the effects of drought or rainfall on the hemlock stands occur the year or second following the event. The trees may be alive but will eventually succumb.

Releasing 10,000 beetles into the middle of a forest sounds like a huge multitude but when one considers the number of trees, the number of beetles released would be hard pressed to even have an impact on an individual tree. The key evaluation data are the crown ratio, and especially transparency. The crown transparency data are very much akin to percent defoliation where the amount of light coming through the crown is directly related to the amount of needles that have been lost. The crown transparency should improve if the HWA populations are brought under control by the beetle. If the crown transparencies do not improve, then the beetles were released too late to help the trees, or the beetles do not reproduce sufficiently to impact the HWA,

P. tsugae Behavior

The behavior of *P. tsugae* after they have been released on a tree is to disperse upwards towards the canopy. As previously mentioned, Dr. Mark McClure has established that the beetles over winter on the tree and is of the opinion that the beetles are higher up in the canopy in the years following release (Personal Communication). Hodek (1973) has reported that Coccinellids readily disperse and this may be true of *Pseudoscymnus*. This could be one of the reasons that recovery numbers of the beetles have been lower than expected for the number of beetles released (see Table 2). In the laboratory rearing cages, the beetles move up to the top of the cages as the day progresses (D. Palmer, NJDA, personal communication).

To try and determine if this is indeed the behavior of these beetles, surveys of certain release trees were conducted using a bucket truck with a 60 ft. boom. The trees had to be located along a road where the bucket truck could get access. This limited the number of sites where the truck could be used. Following the release of 2,500 beetles on a tree at a site in Stokes State Forest on 5/3/01, a ground survey of the area was made on 6/8/01 with the recovery of 6

adult beetles. A second survey was performed on 6/13/01 with the aid of the bucket truck but no beetles were recovered via the ground survey on that date. Table 5 shows the number of beetles recovered at the various heights on the three trees.

The results are quite conclusive. No beetles were recovered at heights less than three meters on any of the trees. The majority of the beetles were recovered at nine and at eight meters. On one adjacent tree beetles were recovered at four and at nine meters. Ground surveys at one and two meters recovered no beetles. In past seasons, no further recoveries would have been made from this site. The data indicates that the *P. tsugae* do move up the tree as the season progresses and even if no recoveries are made at a release site at ground level, the beetles are probably still there, but up in the canopy where they normally cannot be sampled. The beetles also dispersed to adjacent trees but only after they moved up the release tree so the beetles move upwards and outwards from the release site.

Table 5. Distribution of *P. tsugae* per meter.

	# *P. tsugae* per meter		
Height (m)	**Adjacent tree**	**Release Tree**	**Adjacent Tree**
15	0	0	-
14	0	0	0
13	0	-	0
12	0	3	0
11	-	-	0
10	0	2	0
9	0	6	2
8	0	7	-
7	0	3	-
6	-	-	0
5	0	4	0
4	0	0	1
3	0	0	0
2	0	0	0
1	0	0	0

When the *P. tsugae* are reared in the laboratory, they do better on healthy, heavily infested hemlock. Logically, the *P. tsugae* would do better in the same types of conditions in the field.

Evidently, the beetles are still there after they have been released but can be difficult to find because of the lack of food material on the lower branches and the fact that they disperse to the upper canopy. Therefore, when field surveys are made from the ground and no beetles are recovered, it does not mean that the beetles are not there, but that the beetles are in the upper canopy where they cannot be sampled by ground crews. Also, in August when the HWA is no longer active, it becomes difficult to find the beetles. This is probably because the beetles have dispersed.

As the population of *P. tsugae* increases with that of the HWA, they should become easier to locate, as was the case with other species of coccinellids released by the Phillip Alampi Beneficial Insect Laboratory.

The impact of this beetle will be difficult to assess. There may be no numerical response that can be quantified but it will be the absence of the pest and the presence of new growth that may determine whether the program is successful. It will be the absence of the pest rather than the presence of the beetle that will signal the effectiveness of the program.

Time concerns

The long-term success of the program depends on the ability of the beetle to control the HWA or at least suppress it sufficiently so that the trees are able to recover. The HWA has moved into all of the remaining uninfested stands in NJ, which can trigger a 4-year decline in the health of the trees. What is unknown is whether sufficient *P. tsugae* will be released in time to control the HWA. In the past when PABIL staff has released coccinellids, there was a minimum of a three-year lag before any beetles were recovered. *P. tsugae* have been recovered in less time but it is too soon to tell. There are no other cost effective controls available to protect natural hemlock stands at this time

other than biological control.

2003 Plans

In 2003, the PABIL intends to release in the northwestern corner of the state where the hemlocks are still healthy. The goal is to release a maximum number of beetles per site in high value public forested areas in northern NJ in an attempt to boost their reproduction. The releases will be made according to a priority list as follows:

1. State and Federal lands, including natural lands that are located in areas in close proximity to other Hemlock stands where the beetles can redistribute themselves readily and where the crown transparencies are less than 60%.

2. County and municipal lands located in areas in close proximity to other stands where the beetles can redistribute themselves readily.

Sites where no releases will be made in 2003.

- Private forested lands.
- Commercial Nurseries. Pesticides can be used in this situation.
- Commercial landscapes. Pesticides can be used in this situation.
- Homeowner landscapes. Pesticides can be used in this situation.

Reasoning: 1) Insufficient number of beetles available, 2) Areas may not be as conducive to beetle establishment because of pesticide use or, 3) The areas are not strategically located in the problem areas of the state, 4) Additional evaluations of the beetles effectiveness are needed; we must make sure that the beetles are effective before expanding it to include the sites above, 5) the USFS wants us to keep the number of release sites to a minimum until we can be sure that the *P. tsugae* are effective, 6) pesticides can be used to protect trees but not in natural stands.

The area of the state where the majority of the natural hemlock forest is located is in the northern fifth of the state above Interstate 80. That is where the HWA poses the greatest threat to the resource. It is also the area where the HWA is hardest to control because of the inaccessibility of the terrain. Unlike homeowners and commercial landscapers who can use pesticides to effectively control the HWA in the landscape, foresters cannot use pesticides in the natural forest. The cost of insecticide treatment is prohibitive, its effectiveness is minimal and there could be negative ecological effects**.** The USFS and NJ Forest Service have provided funds to help keep the biological control program going and the priority is to save the resource in Northern NJ where the problem is most acute. Once the beetles are well established in the natural stands an effort will be made to protect the trees in the nursery and the landscape.

CONCLUSION

The first five years of the *P. tsugae* program have been successful in that the beetles have become established in our state as evidenced by the recoveries of adults and/or larvae at 12 sites. It is probable that *P. tsugae* is established at more sites, but the dieback of the lower branches in many sites limits the search area survey personnel are able to reach when conducting surveys. Also, the behavior of the beetles to move up into the canopy of the tree following release makes recovery of the beetles difficult. A total of 40,260 beetles were released in NJ forests in 2001, which brings the total to 261,200 beetles that have been released in NJ, which is more beetles than have been released into any other state**.** Releases will be made into some new sites in 2003 concentrating on the remaining hemlock forest that is still healthy. It is too early to tell what the impact of the *P. tsugae* releases will be and the crown conditions have declined in all of the stands despite the releases.

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